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An approach for pervasive homecare environments focused on care of patients with dementia

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Abstract

The aging population and the consequent increase in the incidence of dementias is causing many challenges to health systems, mainly related to infrastructure, like low service quality and high costs. As a solution, the homecare is been stimulated. However, a patient with dementia requires constant care and monitoring from a caregiver, who suffers physical and emotional overload. In this context, this work presents an approach for development of pervasive systems aimed at helping the care of these patients in order to lessen the burden of the caregiver while the patient continues to receive the necessary care.

Keywords: *Pervasive computing; homecare; dementia; ontologies.*

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1. Introduction

The world population is undergoing a process of aging. It is estimated that by 2025 the number of people over 60 exceeds the home of two billion. In parallel to this irreversible phenomenon, most countries will face socioeconomic challenges related to health care due mainly to the increased incidence of chronic degenerative diseases. Among this class of diseases, the most striking are the dementias, accounting for 35.6 million of cases by 2050 [1]. Thus, the current health paradigm, centered at the hospital and clinics, may implicate in the capacity of infrastructure and quality of care in the health systems.

One solution to avoid a collapse in the hospitals is to perform patient care in home environments through homecare services. This type of care aims to provide health services to a patient in their own home instead of moving him to the hospital, by necessity, when the patient is unable to move, or by preference, since it will be in a family environment [2]. However, it is necessary to highlight some relevant issues about care of elderly people with dementia in homecare environments. Being a home environment, the caregiver may be someone of the patient's own family and without knowledge to monitor and assist him correctly. Still, caregivers may become inattentive due to physical and emotional stress brought by about by intense care to patient. Thus, it creates a risk to the health of the patient, once he may have no control or awareness of his actions and also be unable to ask for help in a critical situation [3].

In this context, the concept of pervasive computing can be applied [4]. In a pervasive environment of homecare the monitoring of physiological data, for example, can be collected proactively at various moments of day, without requiring the caregiver to perform it. Besides that, depending on the current context, the environment can adapt itself to the user′s needs and to provide cognitive assistance to the patient.

The development of applications of this kind, however, is not a trivial task, since a pervasive environment can be very heterogeneous depending on the entities that compose it and various computing devices with different processing platforms. So, in addition to attend questions relating to patient care, the pervasive system must deal with issues such as integration of different types of sensors, communication, and data availability for applications transparently.

In the context of pervasive computing applied to the care of patients in their homes, many jobs are found in the literature for monitoring the patients’ health or providing reminders to patients [5-7]. However, the treatment of patients with dementia should to focus on three axis [8]: the diminution of the functional dependence of the patient; the reduction of the burden of the caregiver; and the delay of the cognitive deterioration of the patient.

Given this, the present paper proposes an approach for pervasive environments focused on the care of patients suffering from dementia. This approach includes an architecture for development of pervasive systems, as well as an ontology to represent the domain and possible situations where the environment should react according to a specific context [9]. In our perspective, systems developed in this context preserve patient autonomy, stimulating his cognitive functions and reducing the burden on the caregiver, assisting the care at any stage of the disease offering reminders, cognitive stimulation, or health monitoring.

To present our approach, we organized this paper as follows: in section 2 we present the ontology that represents the domain of the care of patients with dementia at homecare environments. The section 3 presents the proposed architecture and each of the modules that compose it, as well as the ontology developed for the context management of the domain in question. Then, in section 4 we present the conclusions and future steps of the project.

2. Knowledge representation for pervasive homecare

For a pervasive environment to be able to adapt to the current context and react in critical situations it is necessary that the knowledge of the domain is clearly detailed. One the most appropriate ways to achieve this is through the use of ontologies. In an ontology, relationships are formally defined and the semantics of a given relationship is detailed. If these relationships have proper names to identify its meaning, a human can understand it directly, as well as a program can act semantically on given relationship [9].

In this work we propose an ontology to map the existing knowledge in the treatment of patients with dementia in pervasive homecare environments which represents the relationships between the entities and the activities that the patient can perform during his treatment as well as characteristics of the environment. The ontology was developed using the Web Ontology Language – OWL [10], a recommendation from W3C Consortium for this kind of representation, using the Protégé tool [11, 12].

In order to represent a valid context, we held meetings with the healthcare professionals involved in the treatment of patients with the profile adopted, such as physicians and nurses. From the meetings we could clarify how complicated is the treatment of the patients, as learning specific vocabulary of health area, beyond medical guidelines for the management of patient's health. Based on information obtained from the medical staff and literature, we are able to define a set of classes specific to the domain in question. In addition to the entities related to the patient monitoring, such as vital signs, the ontology represents the general classes of the environment, like mobile devices, sensors and rooms.

About the classes, it is interesting to emphasize some information. Not all have instances, seen that were defined as abstract classes and will be used to organize the ontological hierarchy. Thus, no individual can belong only to them. An example of this type of class is *Person*. A person inside the network of homecare should be classified as *Patient*, *Professional* or *Companion*, which are subclasses of *Person*. In turn, *Professional* is also an abstract class, seen that a health professional within the environment can be a *Physician*, *Nurse* or a *PraticalNursing*. And, likewise, *Companion* has subclasses *Responsible* and *Guest*. Unlike abstract classes, these classes are concrete only if they have one or more instances, for example, *Drug* class. From the definition of super classes and the subclasses is created a hierarchy in the ontology, as seen in Figure 1.

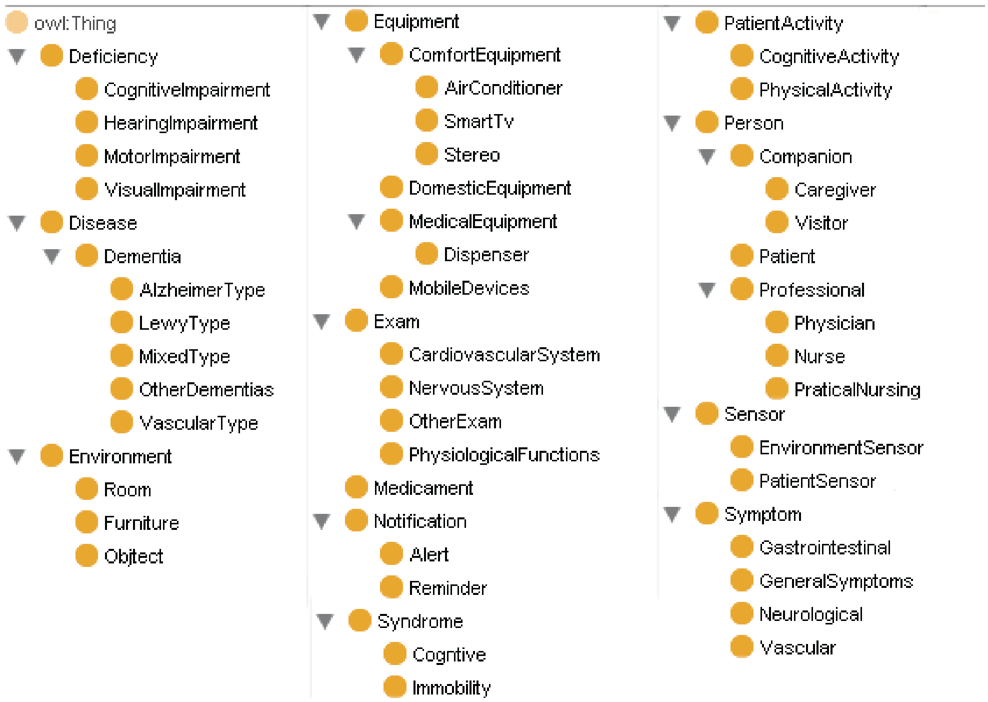

Fig. 1. Classes of the proposed ontology.

However, only with classes it is not possible to provide enough information for the understanding of the ontology. Thus, some properties are used to solve this problem. The properties in ontology can be of two types: datatype properties and object properties. The datatype properties of a class are the characteristics used to describe them, differentiating its individuals. The *Person* class, for example, has the datatype properties *id* and *name*. Subclasses inherit the properties of its parent class. For example, the property *name* represents the name of every individual who belongs to a subclass of *Person* as *Physician* or *Nurse*.

The object properties have the role of relate the individuals from the classes. To illustrate the use of relationships in the ontology, we can create a scenario where the patient has a symptom (e.g. agitation) and needs some medication. In the ontology, the relationship between the classes *Symptom* and *Drug* exists, through property *combat*, indicating that a drug is indicated for a specific symptom. Still, we considered that in pervasive homecare environment each drug must be in a Dispenser (*Drug isIn Dispenser*). In this scenario, the pervasive system could show to a patient, or to a caregiver, through a screen, where the nearest dispenser that contains the drug is indicated for that situation.

3. Architecture for a pervasive system of homecare focused on the treatment of patients with dementia

This section presents the proposed architecture for a pervasive system of homecare, whose main objective is to assist in the treatment of patients with dementia, reducing the caregiver burden and improving his quality of life and the patient's, while the patient remains receiving the necessary care and attention. This architecture takes as reference the work of Freitas et al. [12], which describes a generic architecture for monitoring patients in homecare environments. Soon, from the extension of this architecture, it will be possible to develop systems to assist in the care of patients suffering from dementia. Figure 2 presents the proposed architecture.

The architecture is based on two domains that interact by exchanging information about the entities involved: the cloud computing and the homecare environment. In the cloud computing, there is the ontology that represents the homecare environment, as well as a database that stores inference rules written using the Semantic Web Rule Language - SWRL [13] and queries written using the Semantic Query-Enhanced Web Rule Language - SQWRL [14] to be performed on the ontology. We chose these languages because they can work using all the expressivity of OWL.

The cloud computing also contain the Electronic Health Record system (EHR) with its database, which contains information about patients health, like his medical history, and the applications to manipulate these data. The choice to host the EHR system in the cloud computing has several reasons. Through the cloud storage, many systems can use it in different homecare scenarios and not just one system in particular. That is, with the EHR system hosted in a cloud, any patient that has medical record stored in that database could receive clinical treatment in his house. Besides that, if the environment of treatment changes, e.g., patient leaves his house to be treated in a clinic, the EHR system does not suffer any changes. Still, the users can access their applications and information anywhere and at any time, such that the computing infrastructure is invisible to the users. These reasons also explain the ontology storage in the cloud [12].

The last component in the cloud is the *cloud processing module*. This module is responsible to manage the information circulating on the cloud and to create the ontology containing only specific classes for the current context of homecare environment when necessary. This will be explained in the next paragraphs.

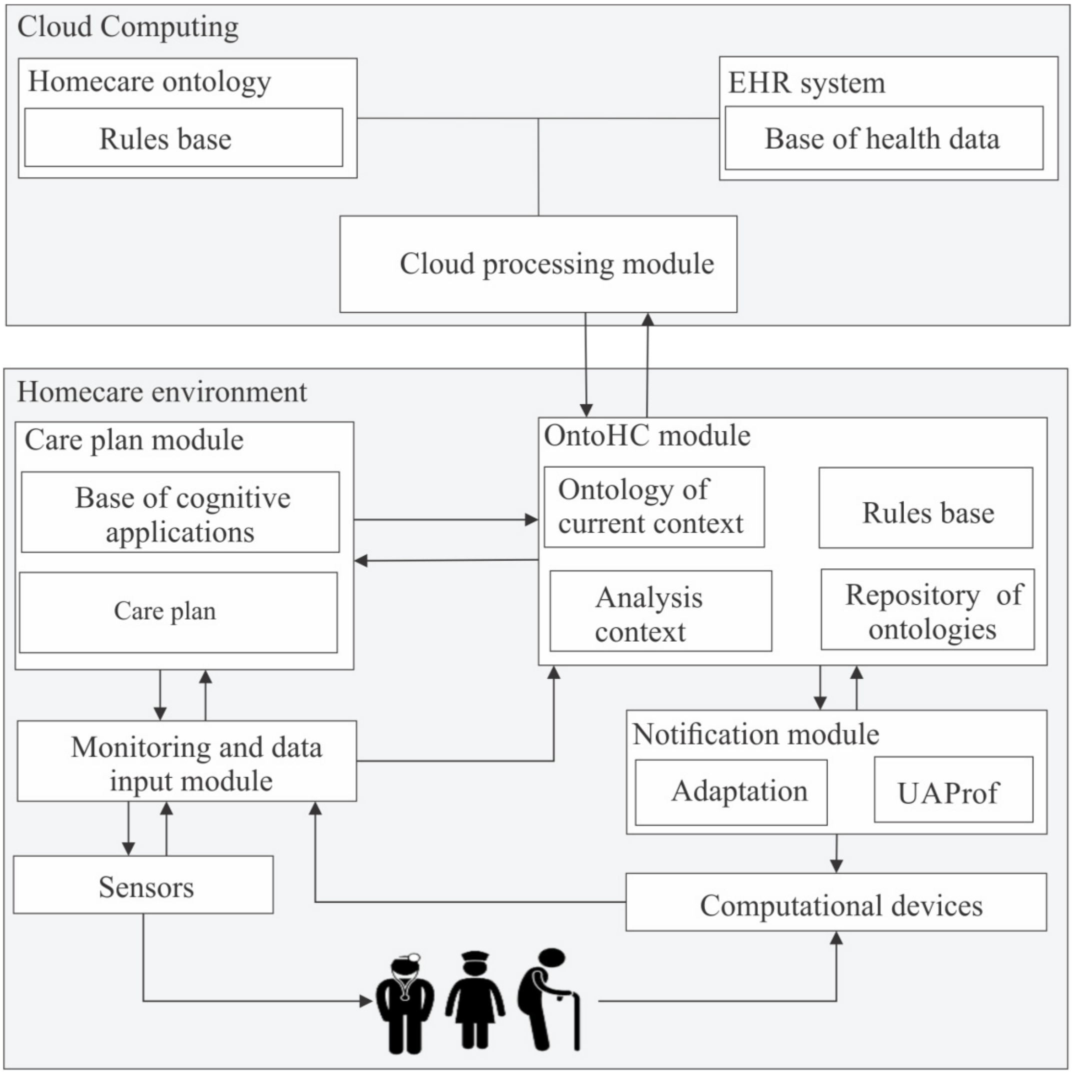

Fig. 2. Architecture for pervasive systems to treatment of patients with dementia in homecare environments.

With the prospect of maintaining interoperability, the communication between the modules of the system is done through the exchange of XML files [15], which have tags that contain important information about the context of a given situation, as the identifier of an entity detected by sensors. For this, each module must contain a parser to handle that information properly.

The operation of a system based on the proposed architecture occurs as follows: sensors perform frequent searches in homecare environment for relevant information to patient care, such as arrival of a physician, changes in vital signs or a patient′s activity. These sensors may have different shapes and different types of data capture. In this work we are not discussing the types of sensors that can be used, since the architecture imposes no restriction on the choice of the devices and how to implement. But in architecture modeling are considered three classes of variables to be monitored: *environmental conditions* as incidence of light, sound, humidity, temperature, among others, that may influence the patient’s health; *physiological data* which includes blood pressure, oxygen saturation level and pulse rate; and *behavioral aspects*, since the change in the patient's behavior may indicate change in disease stage or non-compliance with a prescribed treatment by a physician.

When a sensor captures a context information, the *monitoring and data input module* is notified and inserts this into an XML document, in order to standardize the information to circulate in the system. Then, the file is sent to the *OntoHC module*, considered the core module of the system. The *monitoring and data input module* also acts as a gateway to other information entering the system, directing them to the appropriate modules. For example, a medical prescription which is inserted into the system and forwarded to the *Plan Care module*.

The *OntoHC module* is responsible for handling the ontology that represents the current context of homecare environment. This ontology represents the entities found in the environment in a specific context, in some time. However, some entities need to always mapped, although not really present in the environment, as the entity *Physician*. A physician does not need to be all time in the environment, but it is important to keep him mapped in the ontology, if necessary to send a notification, for example. This type of configuration is set when the homecare services are installed in the patient's home. Besides the ontology, this module has a database that contains a set of inference rules and queries, a repository where there are stored ontologies that have been used by a specific context and the analysis of context component.

After receiving the information captured by the sensors, through the *monitoring and data input module*, the *OntoHC module* uses a set of SQWRL queries, stored in its database, to check if such entities are already mapped in the ontology. In affirmative case, it checks what actions can be triggered and communicates the *notification module* and the module will update this ontology. However, if the ontology of current context does not have the classes, a new ontology must be created with the necessary entities.

To do this, the *OntoHC module* communicates with *cloud processing module* informing which entities must be mapped into the new ontology. In this communication, the system sends a XML document with information about the necessary classes. The *cloud computing processing module* receives these information and, with that, is able to create an ontology containing only information regarding the entities detected (attributes, relationships, constraints, rules of inference and queries).

It’s important to consider that before creating the new ontology, the information that is represented in the ontology of the current context must be including in EHR. To do this, the *OntoHC module* also sends to *cloud computing processing module* another file, which contains the information for each entity represented in ontology of current context. With the help a parser, can manipulate this information and sends it to the EHR system. This ensures that each time a new ontology is created and instantiated with information from EHR, it will have updated information.

After update the database of the EHR system, the cloud processing module creates a new ontological structure only with necessary information of the current context and to perform queries in the database of the EHR system looking for information related to those entities to instantiate this new ontology. Then, the pervasive system sends the new ontology to the *OntoHC module* to be manipulated properly. Thus, the system has a ontology with information of the entities present in the current context stored in a module located in the homecare domain and to execute an application, the system does not need a communication with the computational cloud unless the system detects a new entity in the homecare environment.

With the ontology of current context updated, the *OntoHC module* must verify if the information received from the sensors are related to any activity performed by the patient (e.g. walking) or are a vital signs (e.g. body temperature). This task is performed by the *analysis of context component*.

If the information is about the patient′s health, the module searches, in its rules base, a rule that could be executed to start applications for the users. Among the rules are medical guidelines, which represent the specific medical knowledge that will be applied by the pervasive system (inference rules), for example, when a vital signal exceeds a predefined limit or some adaptation of environment (e.g., turn on an air-conditioning).

In case the information is about any activity of the patient, the *OntoHC module* checks on the P*lan Care module* if this activity is a medical prescription or if the patient is performing an activity on their own.

The plan care module has the function of manage the care plan and the basis of cognitive applications. The care plan includes medical prescriptions for the patient to perform a specific routine of treatment, as measuring blood pressure, medication and exercises that the patient should perform. The medical prescriptions can be inserted in the care plan from any computing device that physician uses and has access to the system, such as a smartphone. In order to standardize, each new prescription is written in an XML document. So when the physician writes a prescription, the application of mobile device sends an XML file to the monitoring and data input module, which forwards the prescription to care plan module.

Each new prescription inserted into the pervasive system will be associated with an event, which is controlled by a timer. So, similarly to the *OntoHC module* checks if a context situation is a medical prescription, the *Plan Care module* verifies, from the time of a prescription, in the ontology of current context if the patient is, or not, following the recommended treatment. With this, the pervasive system can sends a notification to the caregiver or physician, reporting on adherence to treatment or risk situations, as well as sends a compliment to the patient to perform activities.

In order to make the care of patients with dementia more effective, the architecture proposed in this paper includes a repository of cognitive exercises. The exercises are based on typical symptoms of dementia and are focused on cognitive functions such as reasoning, memory and orientation and are stored in XML files. From the prescription of an exercise, the system searches the activity indicated on the basis of activities and then sends it to a computing device of the patient, such as a tablet. With this XML document, the application running on the computing device could build an interface to present the activity to the patient for him to perform it anywhere in the house.

Finally, the information is send by the *notification module*. Unlike the *monitoring and data input module*, the *notification module* has the role of delivering information to the computing device in the homecare environment, whether mobile or fixed, and allows sending information to a physician, who is not at home, through SMS messages, for example.

For this, the *notification module* uses context information (e.g. patient's location) to deliver a notification to closest device, and the needs or disabilities of users. These data can be obtained through SQWRL queries in the ontology of current context. An example of the need for adaptation is when the patient has a visual impairment. Thus, this module should inform the computing device that is necessary to increase the font size.

Still, the module considers the device profile using the User Agent Profiling Specification (UAProf) [16]. Each UAProf document provides hardware and software characteristics of a specific device, as capability of receive images and files. Then, with the union of data from the ontology and the capabilities of devices, it is possible customize the interface to final user, considering his preferences and needs.

The interaction between the notification module and pervasive devices also occurs through XML files. Thus, at the time the notification module communicates with a computing device it also sends a document with information to be presented to the user on the his computational device. As main purpose of this paper is to present the approach for pervasive systems, so we are not discussing issues related to development of logical and interface applications. However, applications should meet some basic requirements. First, the mobile application should be able to interpret XML documents received by the computing device and present the information to the user, as well as adapting the interface when is needed (e.g. increase buttons size).

The application should also be able to identify and assign permissions to different users of the system, providing interfaces so they perform their tasks. While a patient can only make cognitive exercises and receive notifications, the physician is allowed to register new exercise and new medical guidelines.

For the development of mobile application we suggest the use of any programming language which has a separate logical and interface design. The Android, for example, has described the logic in Java and interface is described in XML [17].

4. Conclusion

With the aging population and the consequent increasing incidence of chronic diseases, such as dementia, the current model of health may become obsolete. The concept of home treatment appears as a good solution to this problem, since, instead of patients going to hospital, medical care is performed directly in their houses.

Considering this, the present paper has presented an approach to pervasive homecare environments focused on the care of patients with dementia in their homes. This approach is composed by an architecture for development of pervasive systems in this context, and an ontology for knowledge representation. Through systems developed from the approach proposed is possible integrate different types of devices found in heterogeneous scenarios, like a homecare environment, and provide the treatment in a way that leaves the patient with the greatest possible independence. It is also possible to monitor the health and activities undertaken by the patient. Consequently, the burden placed on caregivers is decreased, without compromise the patient care.

In order to make patient care more effective, the proposed approach contains a plan of care, which has a base of cognitive exercises. Thus, a system allows the cognitive stimulation from any computing device that the patient uses, depending on the level of their disease, providing a better quality of life.

Thus, with the proposed approach, we believe achieve a significant upgrade in the treatment of patients with dementia in their homes. Besides the cognitive aid, the approach provides that pervasive systems developed from it are able to monitor the patient and inform critical health situations to the caregiver or the responsible physician. We consider also that the system can self-adapt the patient's environment according the context and his needs, for example, turn on an air-conditioning when is hot, to not increase the patient's blood pressure.

However, we still need to upgrade the architecture. A future work may be to add a learning module which can be used to adapt the inference rules of the system according with the profile of each patient, since it is performed manually by the professionals.

Finally, some tests with a prototype in real environments would be invaluable for the proposed approach. Thus, one could analyze the functioning of the system more precisely, and then make available it to users.

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